SEAT NO. ME-23500 9

NED UNIVERSITY OF ENGINEERING & TECHNOLOGY

MASTER OF ENGINEERING (MECHANICAL)
FALL SEMESTER EXAMINATIONS 2024

Time: 3 Hours | **Dated:18-DEC-2024** | **Max.Marks:60**

MICRO-& NANO-ELECTROMECHANICAL SYSTEMS - MC-539

Instructions: Attempt All Questions

1. Select the best answer: (20)
   1) C_{60} is also known as _____ (bucky ball, bulky ball, graphene).
   2) Microfluidic channels may be formed using _____ (organic, inorganic, both) materials.
   3) MOS based gas sensor use _____ (optical, electrochemical, acoustic) principle.
   4) _____(optical, electrochemical, acoustic) gas sensors work based on the changes in the resistance of sensitive materials
   5) Acoustic MEMS gas sensors may be used as lung cancer biomarker devices (True, False).
   6) Happy seeder technology is used in reduction of _____ (industrial, vehicular, agricultural) waste.
   7) _____ (SWCNTs, MWCNTs, Fullerenes) are made up of multiple concentric graphene cylinders.
   8) PEM is used in _____ (Fuel cells, artificial muscles, molecular machines).
   9) For X-rays, the high temperature requirement is a limitation for _____ (CNT based device, thermionic cathode, both).
   10) Inkjet printers are example of _____ (thermal, magnetic, optical) actuators.
   11) _____ (magnetic, electrical) stimulation of brain using MEMS coils has found better results.
   12) In addition to monitor pollutant gases, MEMS based gas sensors are also used for pipeline leakage detection. (True, False)
   13) Electrostatic actuators are suitable for low power operation at low frequencies. (True, False)
   14) Lab-on-a-Chip and Micro Total Analysis System are essentially the same. (True, False)
   15) 2nd generation digital micro-fluids are known as Lab-on-a-Chip. (True, False)
   16) Lithography, etching, electroplating and thin-film deposition processes are nano-fabrication processes, (True, False)
   17) Thermal actuators may also be formed with a single material. (True, False)
   18) Neurotechnologies are related to _____.
   19) SEM stands for _____.
   20) The key difference between ADXL 335 and ADXL 345 is _____.

2. (a) What is meant by VOC, $PM_{2.5}$, and PM_{10}? (2)
   (b) Draw the schematic diagram of (i) MOS and (ii) Chemi-resistive, gas sensors. (2)
   (c) For what purpose photocatalytic oxidation technique is used? (1)
   (d) Briefly show the pros and cons of following gas sensing techniques; (3)
   (i) Electro-chemical, (ii) Optical, and (iii) Acoustics
   (e) How does the SAW gas sensor work? (2)

3. (a) Write the chemical formula of Fullerenes. C_{60} (1)
   (b) What are the three properties of Carbon Nano Tubes? (1.5)
   (c) Draw the schematic diagrams of following production methods for CNTs; (4.5)
   (i) Laser Method (ii) Arc Discharge Method (iii) CVD Method
   (d) Enlist at least two advantages of CNT based X-ray device over conventional. (2)
   (e) Explain the concept of molecular gears and pumps. (1)

4. (a) What are the typical values of voltage and torque of a electrostatic driven micro-motor? (1)

(b) The intrinsic carrier concentration of Silicon at room temperature is 1.5×10^{10} per cm^3. A Silicon piece is doped with Phosphorus to a concentration of 2×10^{18} per cm^3. The mobility of electron and holes is the Silicon is approximately 1500 cm^2/V-s and 500 cm^2/V-s, respectively. (3)

i. Find the conductivity of the doped bulk Silicon.

ii. Find the resistance of doped bulk Silicon, if the length and area of cross section (1)

iii. of Silicon is 10 µcm and 2.0 µcm2, respectively. (1)

iv. What would be the power requirement if the bias current is 2 mA?

(b) An Ohmic heater is located in the middle of a suspended fixed-fixed cantilever as shown below. The beam is made of silicon nitride and the metal leads are made of Aluminum.

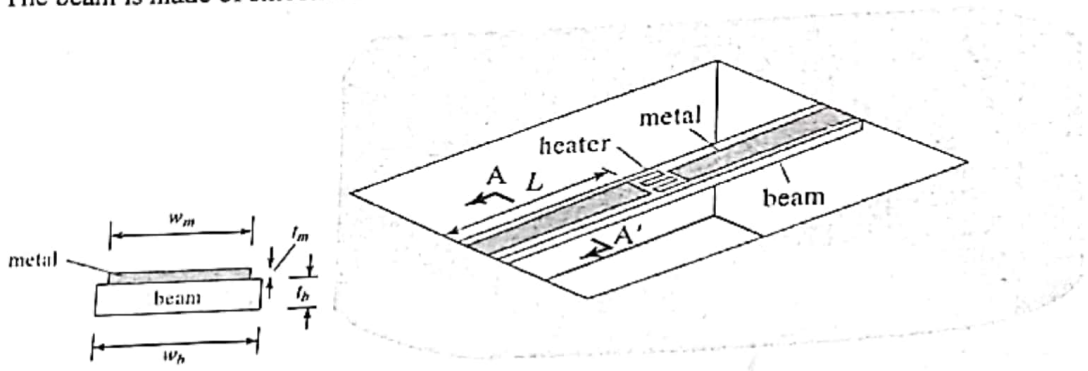

Fig. 1

v. Find the numerical value of the thermal resistance experienced by the heater. Assume the width of the beam is 10 µm with L= 200 µm. and the thickness of both aluminum and silicon nitride is 10.0 µm each. (2)

vi. What would be the steady temperature if the input power to the heater is 15 mW. Assume that the silicon bulk stays at room temperature (i.e. 25°C) and the thermal conductivity of Aluminum and silicon nitride is 240 and 5 W/mK, respectively. (2)

5. (a) Briefly describe the following microfluidic actuation mechanisms: (2)
(i) Magneto-hydrodynamic effect
(ii) Electro-hydrodynamic effect

(b) Illustrate the following active and passive micro-mixing strategies for fluids:
(i) Periodic injection (ii) High energy collision (iii) Main stream injection (3)

(c) Two cantilever beams of the same length and material, one with a cross section of 100 µm by 5µm and second one with 50 µm by 8 µm are shown in Fig.2. Which one is stiffer or resistant to flexural bending? (2)

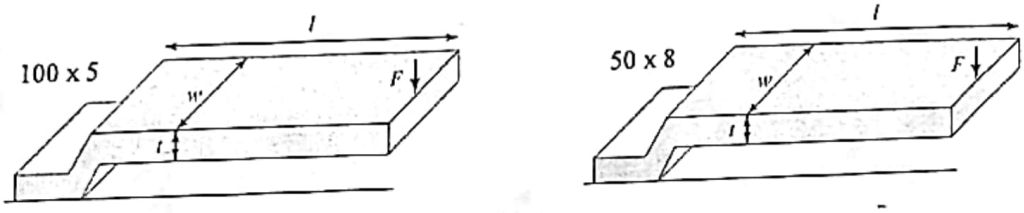

Fig. 2

(c) Explain the purpose of stream shown below in Fig. 3 : (1)

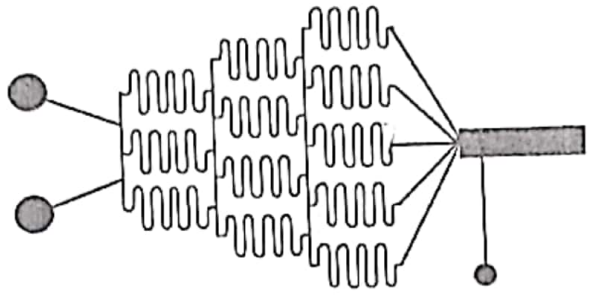

Fig. 3

(d) Illustrate the following steps of a droplet in a digital microfluidic system: (2)

(i) Formation
(ii) splitting
(iii) merging and
(iv) translocation/transportation

Note: You may need to use the following:

$$n_0 p_0 = n_i^2 \qquad \rho \equiv \frac{1}{\sigma} = \frac{1}{\sigma_n + \sigma_p} = \frac{1}{q(\mu_n n + \mu_p p)}. \qquad R = \rho \frac{l}{wt}.$$

$$F_{\text{electric}} = \frac{1}{2}\frac{\varepsilon A}{d^2} V^2 = \frac{1}{2}\frac{CV^2}{d}$$

$$\frac{1}{r} = \frac{6w_1 w_2 E_1 E_2 t_1 t_2 (t_1 + t_2)(\alpha_1 - \alpha_2)\Delta T}{(w_1 E_1 t_1^2)^2 + (w_2 E_2 t_2^2)^2 + 2w_1 w_2 E_1 E_2 t_1 t_2 (2t_1^2 + 3t_1 t_2 + 2t_2^2)}$$

$$\theta = l/r. \quad , \quad R = \rho \frac{l}{A}. \quad , \quad K_m = \frac{F}{d} \; : \quad , \quad d = \frac{Ft^3}{12EI}. \quad , \quad I = \frac{wt^3}{12} \quad , \quad I = \frac{\pi R^4}{4}.$$

Good Luck